EPA Science Advisory Board
Proposed Project
Draft (April 10, 2003)

Project Title/Subject: An Integrated Research Approach for Nitrogen

Requesting Organization/Office: Self-Generated Project

Requesting Official: N/A

Program Contact: N/A

Background:

The chemical elements N, C, P, O and S are all necessary for life. With one exception, they are generally available in global reservoirs to sustain life forms ranging from single-cell organisms to vertebrates. It is ironic that while N has the greatest total abundance, it is also the element that is the least readily available to sustain life. The total amount of N in the atmosphere, soils, and waters of the Earth is ~4 x 10^{21} g -- more than the mass of all five of these other elements combined (Mackenzie, 1998). More than 99% of this N is not available to > 99% of living organisms. The reason for this seeming contradiction is that while there is an abundance of N in nature, it is almost entirely in a chemical form (N_2) that is not usable by most organisms. Breaking the triple bond holding the two nitrogen atoms together requires a significant amount of energy--energy that can be mustered only in high temperature processes or by a small number of specialized N-fixing microbes.

N compounds in nature can be put into two groups – non-reactive and reactive. Non-reactive N is N_2. Reactive N (Nr) includes all biologically active, photochemically reactive, and radiatively active N compounds in the atmosphere and biosphere of the Earth. Thus Nr includes inorganic reduced forms of N (e.g., NH_3, NH_4^+), inorganic oxidized forms (e.g., NO_x, HNO_3, N_2O, NO_3^-), and organic compounds (e.g., urea, amines, proteins, nucleic acids).

In the pre-human world, creation of Nr from N_2 occurred primarily by two processes, lightning and biological nitrogen fixation (BNF). Nr was not accumulating in environmental reservoirs because microbial N fixation and denitrification processes were approximately equal (Ayres et al. 1994).

This is no longer the case. Nr is now accumulating in the environment (Vitousek et al. 1997). During the last few decades production of Nr by humans has been greater than from natural terrestrial systems at the global scale. There are three main causes: 1) widespread cultivation of legumes, rice, and other crops which promote conversion of N_2 to organic N by BNF, 2) combustion of fossil fuels which converts both atmospheric-N_2 and fossil-N to reactive NO_x, and 3) the Haber-Bosch process, which converts non-reactive N_2 to reactive NH_3 to sustain food production and some industrial activities. In the United States, human activities control the creation of Nr. BNF by unmanaged ecosystems is on the order of 10 TgN/yr (C. Cleveland, personal communication). Input of Nr from human activities (fertilizer use, fossil fuel combustion, cultivation-induced BNF) totals ~24 TgN/yr (Howarth et al., 2002).

Circulation of anthropogenic Nr in the atmosphere, hydrosphere and biosphere of the Earth has a wide variety of consequences that are magnified with time as Nr moves along its biogeochemical pathway. The same atom of Nr can cause multiple effects in the atmosphere, in terrestrial ecosystems, in freshwater and marine systems, and on human health. These remarkable changes in the N cycle of the Earth have resulted in a wide variety of beneficial and detrimental changes in the health and welfare of people and ecosystems. A large portion of the human population of the world is sustained today because Nr is provided as synthetic fertilizers and cultivation-induced BNF (Smil, 2000). But there also are some significant worrisome consequences. First, Nr is widely dispersed by hydrologic and atmospheric transport processes. Second, Nr is accumulating in the environment because Nr creation rates are greater than Nr removal rates through denitrification to non-reactive N_2. Third, Nr creation and accumulation is projected to continue to increase in the future as human populations and per-capita resource use increase. Fourth, Nr accumulation contributes to many contemporary environmental problems—for example:

- NOx, a product of combustion, is widely recognized to contribute to urban air pollution and acid precipitation;
- runoff from nitrogen fertilizers is widely recognized source of water pollution;
- concentrated animal feeding operations are increasingly recognized as another source of nitrogen releases to water;
- some nitrogen compounds (N_2O) are greenhouse gases;
- nitrogen deposition has recently been shown to affect forest and grassland productivity and biodiversity.

Whereas most of these nitrogen problems are typically addressed separately, research is increasingly indicating that these nitrogen problems are linked. That is, for example, the same nitrogen that produces urban air pollution can also contribute to water pollution (Galloway et al., 2003).

The purpose of this SAB study is to clarify the extent of linkage among the nitrogen environmental problems, and to explore the implications of these linkages for nitrogen management at the US EPA.

Why Should the SAB Review This Project:

The combination of human dominance in the creation of Nr in the United States, its accumulation in environmental systems and the resulting impacts on people and ecosystems has been the basis for a number of EPA research programs and regulatory activities. However, just as the impacts of Nr accumulation are inter-connected, so should be the programs that address the impacts of, and controls on, reactive N. It is the initial assessment of the SAB that EPA's research programs on N are not integrated, and that this lack of integration can cause groups within EPA to work at cross purposes. For example, EPA has been increasing concerned about the Nr releases from concentrated animal feeding operations (CAFOs). There are several different groups in EPA that are addressing losses to air and water, and it is critical that management programs and regulatory actions be developed to ensure that actions taken to control one type of loss to the environment (e.g., water) do not exacerbate losses to other parts of the environment (e.g., air) (NRC, 2003).

The SAB is well positioned to assess the degree of integration among the current EPA programs, and to make recommendations on how to improve the integration such that EPA develops a coordinated Nr research program.

Charge Questions: The charge of the project is organized in a hierarchy of charge questions that illustrate the issues, how they connect, what is needed from EPA and what can be provided to EPA.

Level One – What are the Nr problems?

- From EPA – Problems being addressed by policy or being researched now by EPA?
- From others – Problems being addressed by policy or being researched now by other agencies?
- To EPA – An assessment of research that they need to do to "fill in the gaps" about the Nr problems themselves.

Level Two – What are the linkages among/between the different Nr problems?

- From EPA – Linkages they can identify among/between their own Nr research efforts and those of others? What are the linkages among EPA programs to manage Nr?
- To EPA – A set of research needs on linkages.

Level Three – What are the benefits of integrated Nr management?

From EPA – Their perceptions, if any?

To EPA – A prioritization, based on the significance of positive impacts, of the research needs on linkages.

To EPA – Encouragement to pursue integrated management and to take advantage of the research.

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Tentative Schedule and Committee: This assessment requires a substantial investment in time by the SAB and by relevant EPA program officers. Over an 12 month period there would be 2 committee meetings and 2 workshops lasting 2-3 days each. The first committee meeting use materials provided by EPA to make an initial assessment of the N-related research programs and will set the agenda for the first workshop, which will involve relevant EPA program officers. The workshop will focus on understanding EPA's research program on N in the different offices and the linkages among programs. The second workshop will follow up from the first workshop, as needed, but will focus on the N-related programs in other agencies, such as the USDA and the DOE. Each workshop will have about 1 day for meeting with the only the committee, which will evaluate what it heard at the workshop, interpret how the scientific goals of the various programs meet EPA's need to understand how anthropogenic N affects people and ecosystems, and organize to write the draft final report. The second committee meeting will be near the end of the project and will be used review the committee's draft the final report. The report will recommend actions to be taken to develop an integrated N research program that is coordinated within EPA and the steps that should be taken to develop stronger interactions with other relevant agencies.. The initial meeting of the subcommittee assigned to this project would be in late 2003, and the final report should be completed near the end of 2004.

Budget: A Panel of approximately 12 people will meet four times (2 meetings and 2 workshops) for 2-3 days each. Members of the Panel will be experts in limnology, ocean ecosystems, estuarine ecosystems, water supply, wastewater treatment, ambient air pollution, stratospheric ozone depletion, agriculture, wetlands, etc. Panelists would need to prepare for the first meeting and do some work between meetings, so I would estimate 5 days of work per panelist per meeting. This would result in 20 days of work per panelist for the project, or a full person-year of work for the project as a whole. An SAB staff person would probably need to work on this project half-time for eighteen months. In addition, panelists would need travel expenses to attend the meetings, the SAB would incur the expenses of staff and contractor support for this effort, and the Agency staff would spend some time providing information and participating in the workshops. It is likely that papers will need to be commissioned on specific aspects of N research. The EEC cannot estimate these costs at this time.

Quality Management/Quality Assurance: SAB Executive Committee Oversight of Special Panel Activities; Peer Review of any papers commissioned; consultation with Agency senior managers on project and with their designated staff.

Outcomes of the Study

The study will identify key components of N-related research that are missing from the EPA's research agenda. It will assess the current degree of interaction among the programs and indicate whether ways to provide additional integration among programs within EPA and with other agencies.. Both of these assessments will enable EPA to have a more efficient and integrated research program that will permit a stronger foundation for management and regulation of environmental N. They also will enable EPA to better leverage their programs with those of other agencies.

References: (note these need to be revised)

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